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**Prior Art Translation of German Patent DE 198 54 463 C 1**

METHOD FOR REDUCING ROTARY MOTIONS ABOUT A TRANSVERSE AXIS DURING THE BRAKING OF A MOTOR VEHICLE

Not a Sub. Spec.
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Field of the Application

The present invention relates to a method for reducing rotary motions about a transverse axis during the braking of a motor vehicle, according to the definition of the species in Claim 1.

An antilock brake system is known from DE 197 13 920 which is installed in the hydraulic braking system of a commercial vehicle for regulating the braking force. The antilock brake system goes into action as soon as an excessively high slippage occurs at the wheels during a braking procedure, that is, when the vehicle speed no longer corresponds to the circumferential speed of the wheels, even under consideration of a tolerance range. The antilock brake system includes rotational speed sensors for measuring the wheel speed, a regulating and control unit in which the measured wheel speeds are compared with setpoint values, as well as actuators for influencing the braking force, to which are applied command signals, which are ascertained according to a regulating instruction deposited in the regulating and control unit.

In strong braking procedures on an inclined roadway the problem may arise that the braking forces build up such a high torque about a transverse axis through the tire contact points of the wheels lying in front in the travel direction, that the vehicle rolls over. Even a slight lifting of the wheels off the roadway or just only a significant reduction of the contact patch force of the wheel restricts travel safety, because the unloaded wheels are only able to transmit reduced forces, or rather no lateral and longitudinal forces. To prevent rollover about a transverse axis, it is provided in DE 197 13 920 A1 that, in the case of an antilock brake system activated at the rear axle of the commercial vehicle, the braking pressure at the front axle is limited to a predetermined degree. In that way it is avoided that the braking torque at the front axle becomes substantially greater than the braking torque at the rear axle.

This procedural manner has the disadvantage that, in favor of travel stability, the braking force is not used in optimal fashion, because the braking pressure at the front axle is set to a constant value, independently of external conditions, such as the topography of the terrain. To be sure, in one expedient further development it is provided that a setpoint deceleration shall be assigned to the predefined braking pressure, and the braking pressure shall be manipulated in such a way that the actual deceleration is adapted to the setpoint deceleration; however, an optimal utilization of all reserves in braking force is not able to be implemented even using this braking force regulation.

The present invention is based on the problem of increasing driving safety of a motor vehicle in braking procedures on an inclined roadway.

According to the present invention, this object is achieved by the features of Claim 1.

The introduction of an inclination-dependent and geometry-dependent reference deceleration makes it possible, in response to critical braking situations during mountainous terrain travel, to reduce the braking force of particularly one wheel brake, and thereby to decrease rollover torque about the center of tire contact of the decelerated wheels transversely to the vehicle's longitudinal axis. Hereby, rollover motions are suppressed or at least reduced, with the result that the following wheels are able to absorb the greatest possible wheel forces, and both the manoeuverability and the vehicle stability are improved.

The danger of rollover appears in the case of vehicles having a high center of gravity and a short wheel base in response to braking manoeuvers carried out in a straight line on an inclined roadway, in particular when, by conditions of construction, the engine is positioned close to an axle, and the vehicle is traveling downhill with this axle in front. In this case, the overall center of gravity of the vehicle is shifted in the direction of the axle running ahead, with the result that there is only a slight distance of the center of gravity from the axle and a slight torque restoring the vehicle to road position. The restriction of maximum braking deceleration to the reference deceleration, which, on account of the consideration of the roadway inclination lies below the corresponding maximum value for a level roadway, ensures that, during the braking procedure, the rollover torque is always smaller than the

restoring torque. Rollover of the vehicle is excluded, and travel safety is thereby increased substantially.

Expediently, the reference deceleration has a weighting factor applied to it. A weighting factor having a maximum of one marks the rollover boundary of the reference deceleration; in order to maintain a safety factor, it may be indicated that the weighting factor should be slightly reduced. In addition, if necessary, it may also be expedient to maintain an even greater safety factor from the rollover boundary, in order to take into account dynamic components of a pitching motion of the vehicle construction, which could be superimposed on the rollover motion and amplify the danger of rollover. Besides, because of the reduced braking forces, the pitching motions are also reduced.

The determination of the system deviation by making a comparison of the vehicle deceleration as the actual value and the reference deceleration as the setpoint value is performed in the regulating and control unit. The system deviation is corrected according to a deposited regulating instruction, and the regulating and control unit produces a command signal, corresponding to the regulation, for setting the braking force of the vehicle brake, particularly the wheel brake. The reference deceleration may be represented as a trigonometric function of the roadway inclination, and is a linear function of additional, vehicle-specific, geometrical parameters and constants.

In a first expedient embodiment, a measuring signal is used as the actual vehicle deceleration, which is picked up as the measured value of an acceleration sensor. The acceleration sensor measures the longitudinal acceleration of the vehicle as to quantity and direction. The deceleration of the vehicle is in this case to be regulated so that a reference deceleration represented as a cosine function may not be exceeded.

According to another expedient embodiment, the regulation may also be carried out without an acceleration sensor. In this case, the actual vehicle deceleration is ascertained computationally by differentiation of a vehicle reference speed, which may, for example, be available for the regulation of the braking force in an antilock brake system. In this case, as opposed to the method having the measured vehicle deceleration, the reference deceleration is

advantageously decreased by a quantity which may be represented as a sine function of the roadway inclination.

According to one preferred embodiment, the roadway inclination is measured, for example, using an inclination sensor, and may thereby be supplied currently updated to the regulating and control unit as an input signal, and drawn upon for the calculation of the reference deceleration. This method has the advantage of using a current value of the roadway inclination in each case, so that at any point in time an optimal value for the reference deceleration may be determined.

However, according to one further embodiment, one can do without the inclination sensor. In this case, a constant value is specified for the roadway inclination which is advantageously oriented towards the maximum climbing ability of the vehicle, to make sure that rollover is prevented for the whole gamut of road inclinations the vehicle is able to manage.

Further advantages and expedient specific embodiments may be inferred from the additional claims and the drawing, in which a braking system is shown as a block diagram.

Engine regulating and control unit 1 is used avoiding the rollover motions of an engine-driven four wheel vehicle during braking operation on an inclined roadway. Such rollover motions, in which the vehicle executes a motion about a rollover axis that is transverse to the vehicle's longitudinal axis, may appear during the braking of the wheels using maximum braking force in downhill travel, the danger of rollover existing for the case that, conditioned upon its construction, the vehicle has a high center of gravity, a short wheelbase and/or an overall center of gravity shifted in the direction of a rollover axis, for example, when the engine is mounted close to one of the wheel axes. If the vehicle travels downhill with that axle ahead in whose direction the vehicle's overall center of gravity has been shifted, then there is the danger that, during strong braking, the restoring, stabilizing torque of the vehicle, which is generated by the center of gravity and the distance from the rollover axis, is no longer sufficient to compensate for the braking torque about the rollover axis. Such a typical braking event may occur in the case of small vehicles having a back engine, which travel backwards on downhill stretches having steep inclinations, and is decelerated to a maximum by the wheel brake. In order to avoid this case, according to the block diagram shown, a regulating

strategy is carried out in the brake operation on an inclined roadway to prevent rollover motions, if necessary also to prevent pitching motions, by direct intervention on the braked wheels. The regulation uses the roadway inclination as the input quantity.

In regulating and control unit 1, based on acceleration variables, a system deviation $\Delta a$ is formed by subtraction of an actual vehicle deceleration $a_{x,S}$ or $a_{x,R}$ from a setpoint deceleration or a reference deceleration $a_{Ref}$, and this system deviation $\Delta a$ is supplied as input signal to a controller 5 and a submitted to a regulation. Controller 5, on the basis of the deposited regulating instruction, generates, for example, a PID regulation, a regulating signal $S_{St}$, which is supplied as a command signal to an actuator 6 of a wheel brake and which leads to a reduction in the braking force.

A vehicle deceleration angle of inclination, measured via a longitudinal acceleration sensor 2, may be drawn upon as the actual vehicle deceleration. As an alternative to this, a vehicle deceleration $a_{x,R}$ may be considered, which is formed by numerical differentiation of a vehicle reference speed $v_x$ in a differentiator 3. The computation of the vehicle deceleration $a_{x,R}$ in differentiator 3 has the advantage that no longitudinal acceleration sensor is required for measuring the vehicle deceleration. When an antilock brake system is installed, vehicle reference speed $v_x$ is available in any case for ascertaining wheel slippage, so that only differentiation of the reference speed, which is numerically easily executed, has to be carried out to obtain the vehicle deceleration.

Reference deceleration $a_{Ref}$, which is used as reference value for the regulation, is determined in a control unit 4. The reference deceleration is determined as a function of the vehicle geometry roadway inclination $\alpha$, according to the function

$$a_{Ref} = (l_h/h_S \cdot \cos(\alpha) - C_1 \cdot \sin(\alpha)) \cdot g \cdot C_2.$$

The vehicle is taken into consideration via parameters $l_h$ and $h_S$, $l_h$ denoting the horizontal distance and $h_S$ denoting the vertical distance between vehicle's center of gravity and the rollover axis, in each case for a normal position of the vehicle on an even foundation. The acceleration due to gravity is denoted as g, $C_1$ and $C_2$ are weighting factors; the acceleration due to gravity and the weighting factors are supplied to control unit 4

together with the vehicle geometry parameters as input signal "Const." For calculating the reference deceleration $a_{Ref}$.

The value of first weighting factor $C_1$ is a function of the determination of the actual vehicle deceleration. In the case where the actual vehicle deceleration is measured using longitudinal acceleration sensor 2, the value of weighting factor $C_1$ is equal to zero, and the reference deceleration $a_{Ref}$ is calculated only as a function of the cosine function. In the case where the actual deceleration is formed in differentiator 3 by differentiation of vehicle reference speed $v_x$, the value of weighting factor $C_1$ is one.

The measure of slowing down, or rather the prevention of rollover, is set via second weighting factor $C_2$. The maximum value of second weighting factor $C_2$ is one; at this value, reference deceleration $a_{Ref}$ reaches the rollover boundary and the braking forces become so large that rollover of the vehicle can only just be prevented. By reducing weighting factor $C_2$, a safety factor from the rollover boundary is able to be maintained which, in particular, takes into account the superimposed dynamic vibration components.

If weighting factor $C_2$ is further reduced to a value clearly smaller than one, the distance to the rollover boundary also becomes greater. Since the actual maximum vehicle deceleration is oriented towards the value reduced by weighting factor $C_2$, only slight braking forces have to be applied, which lead to a correspondingly lower removal of load from the following wheels, and because of that, to greater vehicle stability.

Angle of inclination $\alpha$ may be measured by an inclination sensor and regularly supplied at time-discrete intervals to control unit 4, for bringing up to date reference deceleration $a_{Ref}$. In this embodiment the computation of reference deceleration $a_{Ref}$ is carried out on the basis of instantaneous, up to date angles of inclination $\alpha$, so that at every computation point in time the up to date angle of inclination is available in control unit 4, and thus the reference deceleration assumes the greatest possible value in each case, and therefore the rollover boundary is pushed out as far as possible.

In case no inclination sensor is available, a constant value is specified as roadway inclination $\alpha$, which, for reasons of safety, has to correspond to a maximum value. At a maximum value

of roadway inclination $\alpha$, reference deceleration $a_{Ref}$ assumes a minimum value, so that it is guaranteed that the braking deceleration orients itself to a minimum reference deceleration for all actually appearing road inclinations, and a sufficient distance from the rollover boundary is maintained at all times.

Expediently, the maximum value of roadway inclination $\alpha$ orients itself towards the maximum climbing ability of the vehicle. At a maximum climbing ability of 50 %, the maximum roadway inclination $\alpha_{max}$ is approximately $27^0$, according to the relationship

$$\alpha_{max} = \arctan(0.5)$$

What Is Claimed Is:

1. A method for reducing rotary motions about a transverse axis during the braking of a motor vehicle, the vehicle deceleration ($a_{x,S}$, $a_{x,R}$) being supplied to a regulating and control unit (1) as input signal, and being compared to a reference deceleration $a_{Ref}$, and, when the reference deceleration ($a_{Ref}$) is exceeded, a command signal ($S_{St}$) is generated for reducing the braking force of a vehicle brake,
wherein the roadway inclination ($\alpha$) in the longitudinal direction of the vehicle is taken into consideration in the determination of the reference deceleration ($a_{Ref}$), which is computed as a function of the vehicle geometry, according to the trigonometric relationship

$$a_{Ref} = (l_h/h_S \cdot \cos(\alpha) - C_1 \cdot \sin(\alpha)) \cdot g \cdot C_2$$

in which
$C_1$, $C_2$ denote weighting factors,
$l_h$ denotes the horizontal distance between the vehicle's center of gravity and the rollover axis in the normal position of the vehicle,
$h_S$ denotes the vertical distance between the vehicle's center of gravity and the rollover axis in the normal position of the vehicle,
g denotes the acceleration due to gravity and
$\alpha$ denotes the roadway inclination in the longitudinal direction of the vehicle.

2. The method as recited in Claim 1,
wherein the vehicle deceleration ($a_{x,S}$) is measured using a longitudinal acceleration sensor (2) and is taken as the basis for an input signal.

3. The method as recited in Claim 2,
wherein the first weighting factor ($C_1$) is zero.

4. The method as recited in Claim 1,
wherein the vehicle deceleration ($a_{x,R}$) is ascertained by differentiation of a vehicle reference speed ($v_x$) and is taken as the basis for the input signal for the regulation.

5. The method as recited in Claim 4,
wherein the first weighting factor ($C_1$) is one.

6. The method as recited in one of Claims 1 through 5,
wherein the roadway inclination ($\alpha$) is measured in the longitudinal direction of the vehicle and is supplied to the regulating and control unit (1) as the input signal.

7. The method as recited in one of Claims 1 through 5,
wherein the roadway inclination ($\alpha$) in the longitudinal direction of the vehicle is a constant quantity which is stored in the regulating and control unit (1).

8. The method as recited in Claim 7,
wherein the roadway inclination ($\alpha$) in the longitudinal direction of the vehicle is determined from the maximum climbing ability of the vehicle.

9. The method as recited in Claim 8,
wherein it is assumed that the maximum climbing ability is 50 %, and that, correspondingly, the roadway inclination ($\alpha$) in the longitudinal direction of the vehicle is approximately $27^0$.

10. The method as recited in one of Claims 1 through 9,
wherein the regulating intervention takes place in response to downhill travel in the backwards direction.

11. The method as recited in one of Claims 1 through 10,
wherein the second weighting factor ($C_2$) for preventing rollover about a rollover axis inclined transversely to the vehicle's longitudinal axis is selected to be maximally equal to one.

12. The method as recited in one of Claims 1 through 11,
wherein the second weighting factor ($C_2$) for reducing pitching motions takes on a value less than one.

Abstract

In a method for reducing rotary motions during the braking of a motor vehicle, the automobile deceleration is supplied to a regulating and control unit as input signal, and is compared to a reference deceleration, a command signal for reducing the braking force of a vehicle brake being generated when the reference deceleration is exceeded. In order to increase travel safety of a motor vehicle during braking procedures on inclined roadways, the vehicle geometry is taken into consideration in the reference deceleration, and the reference deceleration is calculated as a function of the roadway inclination according to a trigonometric relationship.

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with reference retardation dependent on vehicle geometry and road inclination
for reducing braking force

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ABSTRACT:


CHG DATE=20001004 STATUS=O>The spin reduction method has a regulating and
control device (1) supplied with an input signal (axR,axS) representing the
actual vehicle retardation, compared with a reference retardation (aRef), for
providing a setting signal for reducing the braking force when the reference
signal is exceeded. The reference signal is calculated in

dependence on the
detected road inclination and the vehicle geometry, e.g. the horizontal and
vertical distances between the vehicle center of gravity and the spin axis.

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DE 197 13 920 A1

# (54) Verfahren zur Reduzierung von Drehbewegungen um eine Querachse beim Bremsen eines Kraftfahrzeugs

(57) Bei einem Verfahren zur Reduzierung von Drehbewegungen beim Bremsen eines Kraftfahrzeugs wird einer Regel- und Steuereinheit als Eingangssignal die Fahrzeugverzögerung zugeführt, die mit einer Referenzverzögerung verglichen wird, wobei bei einem Überschreiten der Referenzverzögerung ein Stellsignal zur Reduzierung der Bremskraft einer Fahrzeugbremse erzeugt wird.
Um die Fahrsicherheit eines Kraftfahrzeugs bei Bremsvorgängen auf geneigter Fahrbahn zu erhöhen, wird in der Referenzverzögerung die Fahrzeuggeometrie berücksichtigt und berechnet sich die Referenzverzögerung in Abhängigkeit der Fahrbahnneigung gemäß einer trigonometrischen Beziehung.

**DE 198 54 463 C 1**

 

## Beschreibung

Die Erfindung betrifft ein Verfahren zur Reduzierung von Drehbewegungen um eine Querachse beim Bremsen eines Kraftfahrzeugs nach dem Oberbegriff des Anspruches 1.

Aus der Druckschrift DE 197 13 920 A1 ist ein Anti-Blockier-System bekannt, das in der hydraulischen Bremsanlage eines Nutzfahrzeugs zur Bremskraftregelung eingesetzt wird. Das Anti-Blockier-System tritt in Aktion, sobald beim Bremsvorgang ein übermäßig hoher Schlupf an den Rädern entsteht, wenn also die Fahrzeuggeschwindigkeit auch unter Berücksichtigung eines Toleranzbereiches nicht mehr der Umfangsgeschwindikeit der Räder entspricht. Das Anti-Blockier-System umfaßt Drehzahlsensoren zur Messung der Raddrehzahl, eine Regel- und Steuereinheit, in der die gemessenen Raddrehzahlen mit Sollwerten verglichen werden, sowie Stellglieder zur Beeinflussung der Bremskraft, die von Stellsignalen, welche gemäß einem hinterlegten Regelgesetz in der Regel- und Steuereinheit ermittelt werden, beaufschlagt werden.

Bei starken Bremsvorgängen auf geneigter Fahrbahn kann das Problem auftreten, daß die Bremskräfte ein derart hohes Drehmoment um eine Querachse durch die Radaufstandspunkte der in Fahrtrichtung vorne liegenden Räder aufbauen, daß das Fahrzeug kippt. Bereits ein geringfügiges Abheben der Räder von der Fahrbahn oder auch nur eine signifikante Reduzierung der Radaufstandskräfte schränken die Fahrsicherheit ein, weil die entlasteten Räder nur reduzierte bzw. keine Seiten- und Längskräfte übertragen können. Um ein Kippen um eine Querachse zu verhindern, ist gemäß der DE 197 13 920 A1 vorgesehen, daß im Falle eines an der Hinterachse des Nutzfahrzeugs aktivierten Anti-Blockier-Systems der Bremsdruck an der Vorderachse auf ein vorbestimmtes Maß begrenzt wird. Auf diese Weise wird vermieden, daß das Bremsmoment an der Vorderachse wesentlich größer wird als das Bremsmoment an der Hinterachse.

Diese Vorgehensweise hat den Nachteil, daß zugunsten der Fahrstabilität die Bremskraft nicht optimal ausgenutzt wird, weil der Bremsdruck an der Vorderachse unabhängig von äußeren Gegebenheiten wie der Geländetopographie auf einen konstanten Wert gesetzt wird. Es ist zwar in einer zweckmäßigen Weiterbildung vorgesehen, dem vorgegebenen Bremsdruck eine Sollverzögerung zuzuordnen und den Bremsdruck in der Weise zu manipulieren, daß die Istverzögerung an die Sollverzögerung angeglichen wird; ein optimales Ausnutzen sämtlicher Reserven an Bremskraft ist jedoch auch mit dieser Bremsdruckregelung nicht realisierbar.

Der Erfindung liegt das Problem zugrunde, die Fahrsicherheit eines Kraftfahrzeugs bei Bremsvorgängen auf geneigter Fahrbahn zu erhöhen.

Dieses Problem wird erfindungsgemäß mit den Merkmalen des Anspruches 1 gelöst.

Die Einführung einer neigungs- und geometrieabhängigen Referenzverzögerung ermöglicht es, in kritischen Bremssituationen bei Bergfahrten die Bremskraft insbesondere einer Radbremse zu reduzieren und dadurch Kippmomente um den Radaufstandspunkt der abgebremsten Räder quer zur Fahrzeuglängsachse zu vermindern. Hierdurch werden Kippbewegungen unterdrückt oder zumindest reduziert, mit der Folge, daß die nachlaufenden Räder größtmögliche Radkräfte aufnehmen können und sowohl die Lenkbarkeit als auch die Fahrzeugstabilität verbessert ist.

Die Gefahr des Kippens tritt bei Fahrzeugen mit hohem Schwerpunkt und kurzem Radstand bei geradlinig durchgeführten Bremsmanövern auf geneigter Fahrbahn auf, insbesondere, wenn konstruktionsbedingt der Motor in der Nähe einer Achse angeordnet ist und das Fahrzeug mit dieser Achse voraus bergab fährt. In diesem Fall ist der Gesamtschwerpunkt des Fahrzeugs in Richtung der vorauseilenden Achse verschoben, mit der Folge eines nur geringen Abstandes des Schwerpunkts zur Achse und eines geringen, das Fahrzeug in Straßenlage rückstellenden Moments. Die Beschränkung der maximalen Bremsverzögerung auf die Referenzverzögerung, die aufgrund der Berücksichtigung der Fahrbahnneigung unterhalb des entsprechenden Maximalwertes für eine ebene Fahrbahn liegt, gewährleistet, daß während des Bremsvorganges das kippende Moment stets kleiner ist als das rückstellende Moment. Ein Kippen des Fahrzeugs ist ausgeschlossen, die Fahrsicherheit ist dadurch wesentlich erhöht.

Zweckmäßig wird die Referenzverzögerung mit einem Gewichtungsfaktor beaufschlagt. Ein Gewichtungsfaktor von maximal eins markiert die Kippgrenze der Referenzverzögerung; um einen Sicherheitsabstand einzuhalten, kann es angezeigt sein, den Gewichtungsfaktor geringfügig zu reduzieren. Darüberhinaus kann es gegebenenfalls auch zweckmäßig sein, einen noch größeren Abstand zur Kippgrenze einzuhalten, um dynamische Anteile aus einer Nickbewegung des Fahrzeugaufbaus, welche sich der Kippbewegung überlagern können und die Kippgefahr verstärken können, zu berücksichtigen. Außerdem werden durch die reduzierten Bremskräfte auch die Nickbewegungen reduziert.

Die Ermittlung der Regelabweichung durch einen Vergleich zwischen der Fahrzeugverzögerung als Istwert und der Referenzverzögerung als Sollwert wird in einer Regel- und Steuereinheit durchgeführt. Die Regelabweichung wird gemäß einem hinterlegten Regelgesetz ausgeregelt, die Regel- und Steuereinheit produziert ein der Regelung entsprechendes Stellsignal zur Einstellung der Bremskraft der Fahrzeugbremse, insbesondere der Radbremse. Die Referenzverzögerung ist als trigonometrische Funktion der Fahrbahnneigung darstellbar und hängt linear von weiteren fahrzeugspezifischen, geometrischen Parametern sowie Konstanten ab.

In einer ersten zweckmäßigen Ausführung wird als Ist-Fahrzeugverzögerung ein Meßsignal verwendet, das als Meßwert eines Beschleunigungssensors aufgenommen wird. Der Beschleunigungssensor mißt die Längsbeschleunigung des Fahrzeugs nach Betrag und Richtung. Die Verzögerung des Fahrzeugs ist in diesem Fall so zu regeln, daß eine als Kosinusfunktion darstellbare Referenzverzögerung nicht überschritten werden darf.

Gemäß einer anderen zweckmäßigen Ausführung kann die Regelung auch ohne Beschleunigungssensor durchgeführt werden. In diesem Fall wird die Ist-Fahrzeugverzögerung rechnerisch durch Differentiation einer Fahrzeug-Referenzgeschwindigkeit ermittelt, die beispielsweise für die Bremskraftregelung in einem Anti-Blockier-System zur Verfügung steht. Die Referenzverzögerung wird hierbei gegenüber dem Verfahren mit gemessener Fahrzeugverzögerung vorteilhaft um einen Betrag vermindert, welcher als Sinusfunktion der Fahrbahnneigung darstellbar ist.

Die Fahrbahnneigung wird gemäß einer bevorzugten Ausführung gemessen, beispielsweise mittels eines Neigungssensors, und kann dadurch fortlaufend aktualisiert der Regel- und Steuereinheit als Eingangssignal zugeführt und für die Berechnung der Referenzverzögerung herangezogen werden. Diese Methode hat den Vorteil, jeweils einen aktuellen Wert der Fahrbahnneigung zu verwenden, so daß zu jedem Zeitpunkt ein optimaler Wert für die Referenzverzögerung bestimmt werden kann.

Gemäß einer weiteren Ausführung kann aber auch auf den Neigungssensor verzichtet werden. In diesem Fall wird ein konstanter Wert für die Fahrbahnneigung vorgegeben, der sich vorteilhaft an der maximalen Steigfähigkeit des

Fahrzeugs orientiert, um sicherzustellen, daß bei sämtlichen vom Fahrzeug bewältigbaren Straßenneigungen ein Kippen verhindert wird.

Weitere Vorteile und zweckmäßige Ausführungsformen sind den weiteren Ansprüchen und der Zeichnung zu entnehmen, in der ein Bremssystem als Blockschaltbild dargestellt ist.

Die Motorregel- und -steuereinheit **1** wird Vermeidung von Kippbewegungen eines motorisch betriebenen vierrädrigen Fahrzeugs im Bremsbetrieb auf einer geneigten Fahrbahn verwendet. Derartige Kippbewegungen, bei denen das Fahrzeug eine Bewegung um eine Kippachse quer zur Fahrzeuglängsachse durch die Radaufstandspunkte ausführt, können bei einer Radbremsung mit maximaler Bremskraft bei einer Bergabfahrt auftreten, wobei die Gefahr des Kippens für den Fall besteht, daß konstruktiv bedingt das Fahrzeug einen hohen Schwerpunkt, einen kurzen Radstand und/oder einen in Richtung einer Kippachse verschobenen Gesamtschwerpunkt aufweist, beispielsweise bei einem Einbau des Motors in der Nähe einer der Radachsen. Fährt das Fahrzeug mit derjenigen Achse voraus bergab, in deren Richtung der Fahrzeug-Gesamtschwerpunkt verschoben ist, so besteht die Gefahr, daß bei einer starken Bremsung das rückstellende, stabilisierende Moment des Fahrzeuges, welches durch den Schwerpunkt und den Abstand zur Kippachse erzeugt wird, zur Kompensation der Bremsmomente um die Kippachse nicht mehr ausreicht. Ein derartiger typischer Bremsvorgang kann bei Kleinwagen mit Heckmotor auftreten, die rückwärts Gefällstrecken mit hoher Neigung hinabfahren und über die Radbremse maximal abgebremst werden. Um diesen Fall zu verhindern, wird gemäß dem dargestellten Blockschaltbild bei geneigter Fahrbahn im Bremsbetrieb eine Regelungsstrategie zur Verhinderung von Kippbewegungen, gegebenenfalls auch zur Verhinderung von Nickbewegungen, durch unmittelbaren Eingriff auf die gebremsten Räder durchgeführt. Die Regelung nutzt die Fahrbahnneigung als Eingangsgröße.

In der Regel- und Steuereinheit **1** wird auf der Basis von Beschleunigungsgrößen eine Regelabweichung $\Delta a$ durch Subtraktion einer Ist-Fahrzeugverzögerung $a_{x,S}$ oder $a_{x,R}$ von einer Soll- bzw. Referenzverzögerung $a_{Ref}$ gebildet und diese Regelabweichung $\Delta a$ als Eingangssignal einem Regler **5** zugeführt und einer Regelung unterzogen. Der Regler **5** erzeugt auf der Grundlage des hinterlegten Regelgesetzes, beispielsweise eine PID-Regelung, ein Regelsignal $S_{St}$, das als Stellsignal einem Aktuator **6** einer Radbremse zugeführt wird und zu einer Reduzierung der Bremskraft führt.

Als Ist-Fahrzeugverzögerung kann eine über einen Längsbeschleunigungssensor **2** gemessene Fahrzeugverzögerung $a_{x,S}$ herangezogen werden. Alternativ hierzu kann eine Fahrzeugverzögerung $a_{x,R}$ berücksichtigt werden, die durch numerische Differentiation einer Fahrzeug-Referenzgeschwindigkeit $v_x$ in einem Differenzierer **3** gebildet wird. Die Berechnung der Fahrzeugverzögerung $a_{x,R}$ im Differenzierer **3** hat den Vorteil, daß kein Längsbeschleunigungssensor zur Messung der Fahrzeugverzögerung benötigt wird. Bei Einsatz eines Anti-Blockier-Systems steht die Fahrzeug-Referenzgeschwindigkeit $v_x$ für die Ermittlung des Radschlupfes ohnehin zur Verfügung, so daß lediglich die numerisch einfach durchzuführende Differentiation der Referenzgeschwindigkeit ausgeführt werden muß, um die Fahrzeugverzögerung zu erhalten.

Die Referenzverzögerung $a_{Ref}$, die als Leitgröße für die Regelung dient, wird in einem Funktionsglied **4** bestimmt. Die Referenzverzögerung bestimmt sich in Abhängigkeit der Fahrzeuggeometrie und der Fahrbahnneigung $\alpha$ nach der Funktion

$$a_{Ref} = (l_h/h_s \cdot \cos(\alpha) - C_1 \cdot \sin(\alpha)) \cdot g \cdot C_2.$$

Die Fahrzeuggeometrie wird über die Parameter $l_h$ und $h_s$ berücksichtigt, wobei $l_h$ den horizontalen Abstand und $h_s$ den vertikalen Abstand zwischen Fahrzeug-Schwerpunkt und Kippachse bezeichnet, jeweils für die Normallage des Fahrzeugs auf ebenem Untergrund betrachtet. Mit g wird die Erdbeschleunigung bezeichnet, $C_1$ und $C_2$ sind Gewichtungsfaktoren; die Erdbeschleunigung und die Gewichtungsfaktoren werden dem Funktionsglied **4** zusammen mit den Fahrzeuggeometrie-Parametern als Eingangssignale "Const." zur Berechnung der Referenzverzögerung $a_{Ref}$ zugeführt.

Der Wert des ersten Gewichtungsfaktors $C_1$ hängt von der Ermittlung der Ist-Fahrzeugverzögerung ab. Für den Fall, daß die Ist-Fahrzeugverzögerung mittels des Längsbeschleunigungssensors **2** gemessen wird, ist der Wert der Gewichtungsfaktor $C_1$ gleich Null und die Referenzverzögerung $a_{Ref}$ berechnet sich nur in Abhängigkeit der Kosinusfunktion. Falls die Ist-Fahrzeugverzögerung im Differenzierer **3** durch Differentiation der Fahrzeug-Referenzgeschwindigkeit $v_x$ gebildet wird, beträgt der Wert des Gewichtungsfaktors $C_1$ eins.

Über den zweiten Gewichtungsfaktor $C_2$ wird das Maß der Dämpfung bzw. die Verhinderung des Kippens eingestellt. Der Maximalwert des zweiten Gewichtungsfaktors $C_2$ beträgt eins; bei diesem Wert erreicht die Referenzverzögerung $a_{Ref}$ die Kippgrenze und die Bremskräfte werden so groß, daß ein Kippen des Fahrzeugs gerade noch verhindert werden kann. Durch Reduzierung des Gewichtungsfaktors $C_2$ kann ein Sicherheitsabstand zur Kippgrenze eingehalten werden, der insbesondere überlagerten dynamischen Schwingungsanteilen Rechnung trägt.

Wird der Gewichtungsfaktor $C_2$ weiter auf einen Wert deutlich kleiner als eins reduziert, so vergrößert sich auch der Abstand zur Kippgrenze. Da die tatsächliche maximale Fahrzeugverzögerung sich an dem um den Gewichtungsfaktor $C_2$ verminderten Wert orientiert, müssen nur geringere Bremskräfte aufgebracht werden, die zu einer entsprechend geringeren Entlastung der nachlaufenden Räder und demgemäß zu mehr Fahrzeugstabilität führen.

Der Neigungswinkel $\alpha$ kann über einen Neigungssensor gemessen und in zeitdiskreten Abständen regelmäßig zur Aktualisierung der Referenzverzögerung $a_{Ref}$ dem Funktionsglied **4** zugeführt werden. In dieser Ausführung erfolgt die Berechnung der Referenzverzögerung $a_{Ref}$ auf der Grundlage momentaner, aktualisierter Neigungswinkel $\alpha$, so daß zu jedem Berechnungszeitpunkt im Funktionsglied **4** der aktuelle Neigungswinkel zur Verfügung steht und dementsprechend die Referenzverzögerung den jeweils größtmöglichen Wert einnimmt, die Kippgrenze also soweit wie möglich hinausgeschoben wird.

Für den Fall, daß kein Neigungssensor zur Verfügung steht, wird als Fahrbahnneigung $\alpha$ eine konstante Größe vorgegeben, die aus Sicherheitsgründen einem Maximalwert entsprechen muß. Bei einem Maximalwert der Fahrbahnneigung $\alpha$ nimmt die Referenzverzögerung $a_{Ref}$ einen Minimalwert ein, so daß gewährleistet ist, daß die Bremsverzögerung bei allen tatsächlichen auftretenden Straßenneigungen sich an einer minimalen Referenzverzögerung orientiert und immer ein ausreichender Abstand zur Kippgrenze eingehalten wird.

Der Maximalwert der Fahrbahnneigung $\alpha$ orientiert sich zweckmäßig an der maximalen Steigfähigkeit des Fahrzeugs. Bei einer maximalen Steigfähigkeit von 50% beträgt die maximale Fahrbahnneigung $\alpha_{max}$ gemäß der Beziehung

$$\alpha_{max} = \arctan(0.5)$$

etwa 27°.

Patentansprüche

1. Verfahren zur Reduzierung von Drehbewegungen um eine Querachse beim Bremsen eines Kraftfahrzeugs, wobei einer Regel- und Steuereinheit (1) als Eingangssignal die Fahrzeugverzögerung ($a_{x,S}$, $a_{x,R}$) zugeführt wird, die mit einer Referenzverzögerung ($a_{Ref}$) verglichen wird, und bei Überschreiten der Referenzverzögerung ($a_{Ref}$) ein Stellsignal ($S_{St}$) zur Reduzierung der Bremskraft einer Fahrzeugbremse erzeugt wird, **dadurch gekennzeichnet**, daß die Fahrbahnneigung ($\alpha$) in Fahrzeuglängsrichtung in der Ermittlung der Referenzverzögerung ($a_{Ref}$) berücksichtigt wird, die sich in Abhängigkeit der Fahrzeuggeometrie gemäß der trigonometrischen Beziehung

$$a_{Ref} = (l_h/h_s \cdot \cos(\alpha) - C_1 \cdot \sin(\alpha)) \cdot g \cdot C_2$$

berechnet, worin
$C_1$, $C_2$ Gewichtungsfaktoren
$l_h$ den horizontalen Abstand zwischen Fahrzeug-Schwerpunkt und Kippachse in Normallage des Fahrzeugs
$h_s$ den vertikalen Abstand zwischen Fahrzeug-Schwerpunkt und Kippachse in Normallage des Fahrzeugs
g die Erdbeschleunigung und
$\alpha$ die Fahrbahnneigung in Fahrzeuglängsrichtung bezeichnen.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Fahrzeugverzögerung ($a_{x,S}$) mittels eines Längsbeschleunigungssensors (2) gemessen und als Eingangssignal zugrunde gelegt wird.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß der erste Gewichtungsfaktor ($C_1$) Null beträgt.

4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Fahrzeugverzögerung ($a_{x,R}$) durch Differentiation einer Fahrzeug-Referenzgeschwindigkeit ($v_x$) ermittelt wird und als Eingangssignal der Regelung zugrunde gelegt wird.

5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der erste Gewichtungsfaktor ($C_1$) eins beträgt.

6. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Fahrbahnneigung ($\alpha$) in Fahrzeuglängsrichtung gemessen und als Eingangssignal der Regel- und Steuereinheit (1) zugeführt wird.

7. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Fahrbahnneigung ($\alpha$) in Fahrzeuglängsrichtung eine konstante Größe ist, die in der Regel- und Steuereinheit (1) abgespeichert wird.

8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß die Fahrbahnneigung ($\alpha$) in Fahrzeuglängsrichtung aus der maximalen Steigfähigkeit des Fahrzeugs ermittelt wird.

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß als maximale Steigfähigkeit 50% und entsprechend als Fahrbahnneigung ($\alpha$) in Fahrzeuglängsrichtung näherungsweise 27° angenommen wird.

10. Verfahren nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß der Regeleingriff bei rückwärts gerichteter Bergabfahrt erfolgt.

11. Verfahren nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß der zweite Gewichtungsfaktor ($C_2$) zur Verhinderung von Kippen um eine quer zur Fahrzeuglängsachse geneigte Kippachse maximal gleich eins gewählt wird.

12. Verfahren nach einem der Ansprüche 1 bis 11, dadurch gekennzeichnet, daß der zweite Gewichtungsfaktor ($C_2$) zur Verminderung von Nickbewegungen einen Wert kleiner als eins einnimmt.

Hierzu 1 Seite(n) Zeichnungen

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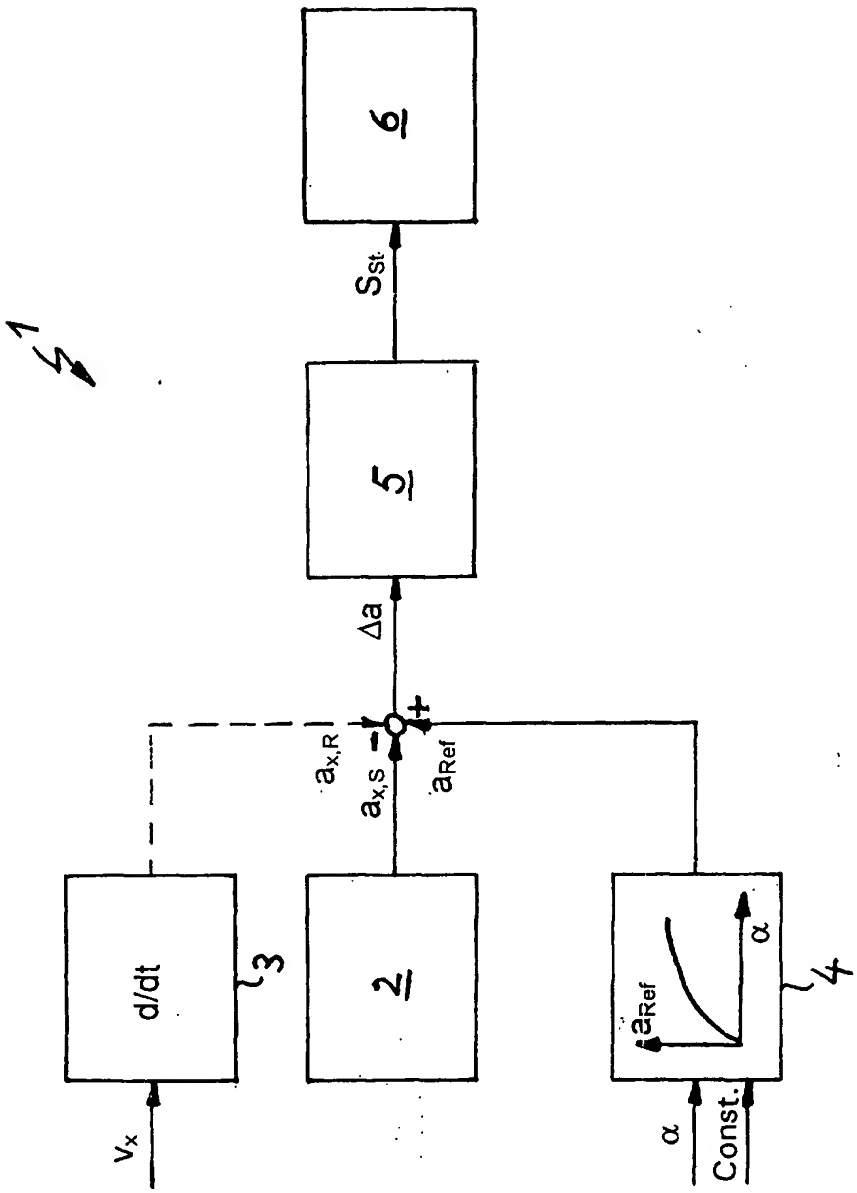

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# METHOD FOR REDUCING SPIN AROUND A TRANSVERSE AXIS AT THE TIME OF BRAKING A MOTOR VEHICLE
[VERFAHREN ZUR REDUZIERUNG VON DREHBEWEGUNGEN UM EINE QUERACHSE BEIM BREMSEN EINES KRAFTFARZEUGS]

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UNITED STATES PATENT AND TRADEMARK OFFICE
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The invention concerns a method for reducing spin around a transverse axis at the time of braking a motor vehicle according to the preamble of Claim 1.

The publication DE 197 13 920 discloses an anti-locking system that is used in the hydraulic braking system of an automobile for braking force control. The anti-locking system goes into action as soon as excessively great slippage takes place on the wheels, therefore if the motor vehicle speed no longer corresponds to the circumferential speed of the wheels, even taking account of a tolerance range. The anti-locking system includes speed sensors for measuring the wheel speed, a regulating and control unit, in which the measured wheel speeds are compared with nominal values, as well as adjusting elements for influencing the braking force, that are acted upon by adjusting signals, which are determined according to a recorded control rule in the regulation and control unit.

In the case of strong braking processes on a sloping road there may appear the problem that the braking forces build up so high a torque around a transverse axis by the wheel stopping point of the wheels lying in front in the direction of travel that the vehicle overturns. A slight lifting of the wheels from the road or even only a significant reduction of the wheel stopping forces reduce the driving safety because the unloaded wheels can transfer only reduced or no lateral and longitudinal forces. In order to prevent overturning around a transverse axis, according to DE 197 13 920 A1 it is provided that in the case of an anti-locking system activated on

the rear axle of the automobile, the braking force is limited on the front axle to a predetermined degree. This prevents the braking moment on the front axle from being significantly greater than the braking moment on the rear axle.

This procedure has the disadvantage that the braking force is not exerted optimally in favor of the driving stability, because the braking pressure in the front axle is set at a constant value independent of external circumstances such as the topography of the terrain. In an advantageous further development it is provided to associate a nominal retardation with the predetermined braking pressure and to manipulate the braking pressure so that the actual retardation becomes equal to the nominal retardation; however, optimal exertion of all reserves of braking force cannot be realized with this braking force regulation.

The invention is based on the problem of increasing the driving safety of a motor vehicle in the case of braking forces on a sloping road.

This problem is solved according to the invention with the features of Claim 1.

The introduction of a gradient- and geometry- dependent reference retardation makes it possible to reduce the braking force, in particular of one wheel brake, in critical braking situations in the case of driving on gradients and thus to reduce tipping moments around the wheel stopping point of the braked wheels transverse to the longitudinal axis of the vehicle. In this way tipping motions are

suppressed or at least reduced, with the consequence that the following wheels can receive the greatest possible wheel forces and both the steering and vehicle stability are improved.

The danger of overturning appears in the case of vehicles with a high center of gravity and short wheel base at the time of braking maneuvers performed in a straight line on a sloping road, in particular when the motor is designed to be close to an axle and the vehicle drives downhill with this axle in front. In this case the entire center of gravity of the vehicle is displaced in the direction of the leading axle, with the consequence of only a short distance between the center of gravity and the axle and a small moment returning the vehicle to the street position. The limitation of the maximum braking retardation to the reference retardation, that is below the corresponding maximum value for a level road taking account of the slope of the road, insures that during the braking process the tipping moment always is smaller than the returning moment. Overturning of the vehicle is excluded, thus the driving safety is significantly increased.

Preferably the reference retardation has a weighting factor. A weighting factor of at most one marks the tipping limit of the reference retardation; in order to maintain a safety margin, it may be indicated to reduce the weighting factor slightly. In addition it may also be advantageous to maintain an even greater distance from the tipping limit in order to take account of dynamic portions from a pitching motion of the vehicle that can overlap the tipping motion and

increase the danger of overturning. In addition, the pitch motions also are reduced by the reduced braking forces.

The determination of the control deviation by a comparison between the vehicle retardation as an actual value and the reference retardation as a nominal value is carried out in a regulating and control unit. The regulation deviation is regulated according to a recorded regulation law, the regulating and control unit produces an adjusting signal corresponding to the regulation for adjusting the braking force of the vehicle brake, in particular the wheel brake. The reference retardation may be represented as a trigonometric function of the road gradient and is linearly dependent on further vehicle-specific, geometric parameters as well as constants.

In a first preferred embodiment a measuring signal is used as an actual vehicle retardation, that is accepted as a measured value of an acceleration sensor. The acceleration sensor measures the longitudinal acceleration of the vehicle according to amount and direction. The retardation of the vehicle is to be regulated in this case so that a reference retardation that may be represented as a cosine function may not be exceeded.

According to another preferred embodiment the regulation also may be carried out without acceleration sensor. In this case the actual vehicle retardation is determined by computer by differentiation of a vehicle reference speed, that is available, for example, for the brake force regulation in anti-locking system. The reference retardation in this case is reduced with respect to the method with measured vehicle

retardation advantageously by an amount which may be represented as a sine function of the road gradient.

The road gradient is measured according to a preferred embodiment, for example by means of a slope sensor, and therefore the regulating and control unit may be provided as a continuously updated input signal and used for calculating the reference retardation. This method has the advantage in each case of using a current value of the road gradient so that an optimal value for the reference retardation may be determined at any moment.

According to a further embodiment the slope sensor also may be omitted. In this case a constant value for the road gradient, that advantageously is oriented to the maximum climbing ability of the motor vehicle in order to make sure that overturning is prevented in the case of all road gradients that may be handled by the motor vehicle.

Further advantages and preferred embodiments are to be deduced from the further Claims and the drawing in which a braking system is shown as a block diagram.

The motor regulating and control unit **1** is used to avoid tipping motions of a motor-driven four-wheel vehicle in brake operation on a sloping road. These tipping motions, in the case of which the vehicle performs a motion around a tipping axis transverse to the longitudinal axis of the vehicle through the vehicle stopping points, may appear in the case of a wheel braking with maximum braking force in the case of traveling downhill, the danger of overturning existing for the case

where the vehicle has a structurally high center of gravity, a short wheel base and/or a overall center of gravity shifted in the direction of a tipping axis, for example in the case of installation of the motor in the vicinity of one of the wheel axles. If the vehicle travels downhill with this axle in front, in the direction of which the overall vehicle center of gravity is shifted, in the case of strong braking there is the danger that the return, stabilizing moment of the vehicle, which is generated by the center of gravity and the distance to the tipping axis, no longer suffices for compensation of the braking moments around the tipping axis. Such a typical braking process may appear in the case of automobiles with a rear engine, that descend backwards over steep grades and are maximally braked via the wheel brake. In order to prevent this case, according to the block diagram a control strategy for preventing tipping motions, in a given case also for preventing pitching motions, is carried out by direct action on the braked wheels in the case of a sloping road. The regulation uses the road gradient as an input value.

A regulation deviation $\Delta a$ is formed by subtraction of an actual vehicle retardation $a_{z,S}$ or $a_{z,R}$ from a nominal or reference retardation $a_{Ref}$ is formed on the basis of acceleration values and this regulation deviation $\Delta a$ is supplied to a regulator **5** and subjected to a regulation. The regulator **5** generates a control signal $S_{St}$ that is fed as an adjusting signal to an actuator **6** of a wheel brake and leads to a reduction of the braking force on the basis of the recorded control law, for example a PID regulation.

A vehicle retardation $a_{z,S}$ measured via a longitudinal acceleration sensor **2** may be used as the actual vehicle retardation. Alternatively, it is possible to take account of a vehicle retardation $a_{z,R}$ , that is formed by numerical differentiation of a vehicle reference speed $v_x$ that is formed in a differentiator **3** for determining the wheel slipping. The calculation of the vehicle retardation $a_{z,R}$ in the differentiator **3** has the advantage that no longitudinal acceleration sensor is needed for measuring the vehicle retardation. In the case of using an anti-licking system the vehicle reference speed $v_x$ us available for determining the wheel slipping directly, so that only the differentiation of the reference speed, that is numerically easy to carry out, must be performed in order to obtain the vehicle retardation.

The reference retardation $a_{z,R}$ , that is used as a guiding value for the regulation, is determined in a function element **4**. The reference retardation is determined depending on the vehicle geometry and the road gradient $\alpha$ according to the function

$$a_{Ref} = (I_h/h_s \; . \; \cos(\alpha) \; - \; C_1 \; . \; \sin \; (\alpha) \; . \; g \; . \; C_2.$$

The vehicle geometry is taken into account via the parameters $I_h$ and $h_s$, $I_h$ designating the horizontal distance and $h_s$ the vertical distance between vehicle center of gravity and tipping axis, in each case considered for the normal position of the vehicle on level ground. The acceleration due to gravity is designated as g, $C_1$ and $C_2$ are weighting factors; the acceleration due to gravity and the weighting factors are supplied to the functional element **4** together

with the vehicle geometry parameters as input signals "const." For calculating the reference retardation $a_{Ref}$ .

The value of the first weighting factor $C_1$ depends on the determination of the actual vehicle retardation. For the case that the actual vehicle retardation is measured by means of the longitudinal acceleration sensor **2**, the value of the weighting factor $C_1$ is equal to zero and the reference retardation $a_{Ref}$ calculated only in relation to the cosine function. If the actual vehicle retardation is formed in the differentiator **3** by differentiation of the vehicle reference speed $v_x$ , the value of the weighting factor $C_1$ amounts to one.

The degree of damping, respectively the prevention of overturning, is adjusted via the second weighting factor $C_2$ . The maximum value of the second weighting factor $C_2$ amounts to one; in the case of this value the reference retardation $a_{Ref}$ reaches the tipping limit and the braking forces are so great that overturning of the vehicle can just be prevented. A safety margin to the tipping limit, that in particular takes account of overlapped dynamic portions of the oscillation, may be maintained by reducing the weighting factor $C_2$.

If the weighting factor $C_2$ again is reduced to a value clearly smaller that one, the distance to the tipping limit also is increased. Since the actual maximum vehicle retardation is oriented to the value reduced by the weighting factor $C_2$, only slight braking forces have to be applied, that lead to a correspondingly lower unlo0ading of the following wheels and correspondingly to more driving stability.

The angle of gradient $\alpha$ may be measured via a gradient sensor and supplied to the functional element **4** regularly at discrete time intervals for updating the reference retardation $a_{Ref}$. In this embodiment, the calculation of the reference retardation $a_{Ref}$ takes place on the basis of instantaneous, updated angles of gradient $\alpha$, so that at any moment of calculation the current angle of gradient is available in functional element **4** and correspondingly the reference retardation assumes the greatest possible value in each case, therefore the tipping limit is extended as far as possible.

For the case that no gradient sensor is available, a constant value is predetermined as a road gradient $\alpha$, that must correspond to a maximum value for safety reasons. In the case of a maximum value of the road gradient $\alpha$, the reference retardation $a_{Ref}$ assumes a minimum value, so that it is assured that the braking retardation is oriented to a minimum reference retardation and a sufficient distance from the tipping limit always is maintained in the case of all actual appearing road gradients.

The maximum value of the road gradient $\alpha$ preferably is oriented to the maximum climbing ability of the vehicle. In the case of a maximum climbing ability of 50% the maximum vehicle gradient amounts to $\alpha_{max}$ according to the relation

$\alpha_{max}$ = arctan (0.5)

approximately 27°.

## Patent Claims

1. A method for reducing spin motions around a transverse axis in the case of braking a motor vehicle, the vehicle retardation ($a_{z,S}$, $a_{z,R}$) that is compared with a reference retardation ($a_{Ref}$) being supplied to a regulating and control unit (1) as an input signal , and in the case of exceeding the reference retardation ($a_{Ref}$) an adjusting signal ($S_{St}$) being generated for reducing the braking force of a vehicle brake, wherein the road gradient ($\alpha$) in the longitudinal direction of the vehicle is taken into account in the determination of the reference retardation ($a_{Ref}$), that is calculated in relation to the vehicle geometry according to the trigonometric relation

$a_{Ref} = (I_h/h_s \; . \; \cos(\alpha) - C_1 \; . \; \sin(\alpha) \; . \; g \; . \; C_2$,

wherein

$C_1$, $C_2$ designates weighting factors

$l_h$ designates the horizontal distance between vehicle center of gravity and tipping axis in the normal position of the vehicle,

$l_h$ designates the vertical distance between vehicle center of gravity and tipping axis in the normal position of the vehicle,

g designates the acceleration due to gravity, and

$\alpha$ designates the road gradient in the longitudinal direction of the vehicle.

2. The method according to Claim 1, wherein the vehicle retardation ($a_{x,S}$) is measured by means of a longitudinal acceleration sensor (2) and used as the basis of an input signal.

3. The method according to Claim 2, wherein the first weighting factor ($C_1$) amounts to zero.

4. The method according to Claim 1, wherein the vehicle retardation ($a_{x,R}$) is determined y differentiation of a vehicle reference speed ($v_x$) and is used as the basis of a regulation input signal.

5. The method according to Claim 4, wherein the first weighting factor ($C_1$) amounts to one.

6. The method according to one of the Claims 1 to 5, wherein the road gradient ($\alpha$) is measured in the longitudinal direction of the vehicle and supplied as input signal to the regulating and control unit (1).

7. The method according to one of the Claims 1 to 5, wherein the road gradient ($\alpha$) in the longitudinal direction of the vehicle is a constant value, that is stored in the regulating and control unit (1).

8. The method according to Claim 1, wherein the road gradient ($\alpha$) in the longitudinal direction of the vehicle is determined from the maximum climbing ability of the vehicle.

9. The method according to Claim 8, wherein 50% is assumed as the maximum climbing ability and correspondingly 27° is assumed as the road gradient ($\alpha$) in the longitudinal direction.

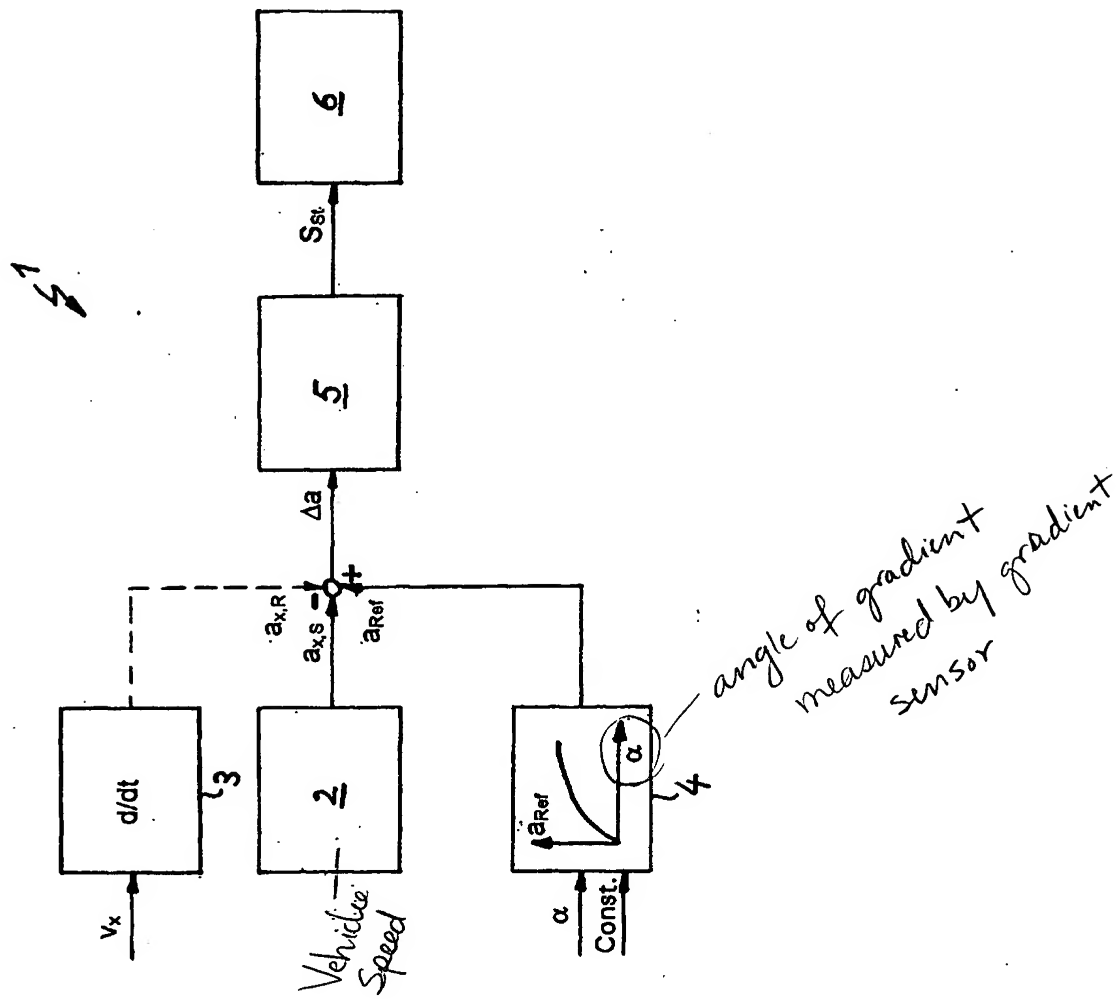
10. The method according to one of the Claims 1 to 9, wherein the regulation takes place in the case of backwards-directed travel downhill.

11. The method according to one of the Claims 1 to 10, wherein the second weighting factor ($C_2$) for preventing overturning around a tipping axis inclined transverse to the longitudinal axis of the vehicle is chosen to be at most equal to one.

12. The method according to at least one of the Claims 1 to 11, wherein the second weighting factor ($C_2$) is assumed to be smaller than one in order to prevent pitching motions.

1 page of drawings appended

DRAWINGS PAGE 1



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# METHOD FOR REDUCING SPIN AROUND A TRANSVERSE AXIS AT THE TIME OF BRAKING A MOTOR VEHICLE
[VERFAHREN ZUR REDUZIERUNG VON DREHBEWEGUNGEN UM EINE QUERACHSE BEIM BREMSEN EINES KRAFTFARZEUGS]

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The invention concerns a method for reducing spin around a transverse axis at the time of braking a motor vehicle according to the preamble of Claim 1.

The publication DE 197 13 920 discloses an anti-locking system that is used in the hydraulic braking system of an automobile for braking force control. The anti-locking system goes into action as soon as excessively great slippage takes place on the wheels, therefore if the motor vehicle speed no longer corresponds to the circumferential speed of the wheels, even taking account of a tolerance range. The anti-locking system includes speed sensors for measuring the wheel speed, a regulating and control unit, in which the measured wheel speeds are compared with nominal values, as well as adjusting elements for influencing the braking force, that are acted upon by adjusting signals, which are determined according to a recorded control rule in the regulation and control unit.

In the case of strong braking processes on a sloping road there may appear the problem that the braking forces build up so high a torque around a transverse axis by the wheel stopping point of the wheels lying in front in the direction of travel that the vehicle overturns. A slight lifting of the wheels from the road or even only a significant reduction of the wheel stopping forces reduce the driving safety because the unloaded wheels can transfer only reduced or no lateral and longitudinal forces. In order to prevent overturning around a transverse axis, according to DE 197 13 920 A1 it is provided that in the case of an anti-locking system activated on

the rear axle of the automobile, the braking force is limited on the front axle to a predetermined degree. This prevents the braking moment on the front axle from being significantly greater than the braking moment on the rear axle.

This procedure has the disadvantage that the braking force is not exerted optimally in favor of the driving stability, because the braking pressure in the front axle is set at a constant value independent of external circumstances such as the topography of the terrain. In an advantageous further development it is provided to associate a nominal retardation with the predetermined braking pressure and to manipulate the braking pressure so that the actual retardation becomes equal to the nominal retardation; however, optimal exertion of all reserves of braking force cannot be realized with this braking force regulation.

The invention is based on the problem of increasing the driving safety of a motor vehicle in the case of braking forces on a sloping road.

This problem is solved according to the invention with the features of Claim 1.

The introduction of a gradient- and geometry- dependent reference retardation makes it possible to reduce the braking force, in particular of one wheel brake, in critical braking situations in the case of driving on gradients and thus to reduce tipping moments around the wheel stopping point of the braked wheels transverse to the longitudinal axis of the vehicle. In this way tipping motions are

suppressed or at least reduced, with the consequence that the following wheels can receive the greatest possible wheel forces and both the steering and vehicle stability are improved.

The danger of overturning appears in the case of vehicles with a high center of gravity and short wheel base at the time of braking maneuvers performed in a straight line on a sloping road, in particular when the motor is designed to be close to an axle and the vehicle drives downhill with this axle in front. In this case the entire center of gravity of the vehicle is displaced in the direction of the leading axle, with the consequence of only a short distance between the center of gravity and the axle and a small moment returning the vehicle to the street position. The limitation of the maximum braking retardation to the reference retardation, that is below the corresponding maximum value for a level road taking account of the slope of the road, insures that during the braking process the tipping moment always is smaller than the returning moment. Overturning of the vehicle is excluded, thus the driving safety is significantly increased.

Preferably the reference retardation has a weighting factor. A weighting factor of at most one marks the tipping limit of the reference retardation; in order to maintain a safety margin, it may be indicated to reduce the weighting factor slightly. In addition it may also be advantageous to maintain an even greater distance from the tipping limit in order to take account of dynamic portions from a pitching motion of the vehicle that can overlap the tipping motion and

increase the danger of overturning. In addition, the pitch motions also are reduced by the reduced braking forces.

The determination of the control deviation by a comparison between the vehicle retardation as an actual value and the reference retardation as a nominal value is carried out in a regulating and control unit. The regulation deviation is regulated according to a recorded regulation law, the regulating and control unit produces an adjusting signal corresponding to the regulation for adjusting the braking force of the vehicle brake, in particular the wheel brake. The reference retardation may be represented as a trigonometric function of the road gradient and is linearly dependent on further vehicle-specific, geometric parameters as well as constants.

In a first preferred embodiment a measuring signal is used as an actual vehicle retardation, that is accepted as a measured value of an acceleration sensor. The acceleration sensor measures the longitudinal acceleration of the vehicle according to amount and direction. The retardation of the vehicle is to be regulated in this case so that a reference retardation that may be represented as a cosine function may not be exceeded.

According to another preferred embodiment the regulation also may be carried out without acceleration sensor. In this case the actual vehicle retardation is determined by computer by differentiation of a vehicle reference speed, that is available, for example, for the brake force regulation in anti-locking system. The reference retardation in this case is reduced with respect to the method with measured vehicle

retardation advantageously by an amount which may be represented as a sine function of the road gradient.

The road gradient is measured according to a preferred embodiment, for example by means of a slope sensor, and therefore the regulating and control unit may be provided as a continuously updated input signal and used for calculating the reference retardation. This method has the advantage in each case of using a current value of the road gradient so that an optimal value for the reference retardation may be determined at any moment.

According to a further embodiment the slope sensor also may be omitted. In this case a constant value for the road gradient, that advantageously is oriented to the maximum climbing ability of the motor vehicle in order to make sure that overturning is prevented in the case of all road gradients that may be handled by the motor vehicle.

Further advantages and preferred embodiments are to be deduced from the further Claims and the drawing in which a braking system is shown as a block diagram.

The motor regulating and control unit **1** is used to avoid tipping motions of a motor-driven four-wheel vehicle in brake operation on a sloping road. These tipping motions, in the case of which the vehicle performs a motion around a tipping axis transverse to the longitudinal axis of the vehicle through the vehicle stopping points, may appear in the case of a wheel braking with maximum braking force in the case of traveling downhill, the danger of overturning existing for the case

where the vehicle has a structurally high center of gravity, a short wheel base and/or a overall center of gravity shifted in the direction of a tipping axis, for example in the case of installation of the motor in the vicinity of one of the wheel axles. If the vehicle travels downhill with this axle in front, in the direction of which the overall vehicle center of gravity is shifted, in the case of strong braking there is the danger that the return, stabilizing moment of the vehicle, which is generated by the center of gravity and the distance to the tipping axis, no longer suffices for compensation of the braking moments around the tipping axis. Such a typical braking process may appear in the case of automobiles with a rear engine, that descend backwards over steep grades and are maximally braked via the wheel brake. In order to prevent this case, according to the block diagram a control strategy for preventing tipping motions, in a given case also for preventing pitching motions, is carried out by direct action on the braked wheels in the case of a sloping road. The regulation uses the road gradient as an input value.

A regulation deviation $\Delta a$ is formed by subtraction of an actual vehicle retardation $a_{z,S}$ or $a_{z,R}$ from a nominal or reference retardation $a_{Ref}$ is formed on the basis of acceleration values and this regulation deviation $\Delta a$ is supplied to a regulator **5** and subjected to a regulation. The regulator **5** generates a control signal $S_{St}$ that is fed as an adjusting signal to an actuator **6** of a wheel brake and leads to a reduction of the braking force on the basis of the recorded control law, for example a PID regulation.

A vehicle retardation $a_{z,S}$ measured via a longitudinal acceleration sensor **2** may be used as the actual vehicle retardation. Alternatively, it is possible to take account of a vehicle retardation $a_{z,R}$ , that is formed by numerical differentiation of a vehicle reference speed $v_x$ that is formed in a differentiator **3** for determining the wheel slipping. The calculation of the vehicle retardation $a_{z,R}$ in the differentiator **3** has the advantage that no longitudinal acceleration sensor is needed for measuring the vehicle retardation. In the case of using an anti-licking system the vehicle reference speed $v_x$ us available for determining the wheel slipping directly, so that only the differentiation of the reference speed, that is numerically easy to carry out, must be performed in order to obtain the vehicle retardation.

The reference retardation $a_{z,R}$ , that is used as a guiding value for the regulation, is determined in a function element **4**. The reference retardation is determined depending on the vehicle geometry and the road gradient $\alpha$ according to the function

$a_{Ref} = (I_h/h_s \; . \; \cos(\alpha) \; - \; C_1 \; . \; \sin\;(\alpha) \; . \; g \; . \; C_2.$

The vehicle geometry is taken into account via the parameters $I_h$ and $h_s$, $I_h$ designating the horizontal distance and $h_s$ the vertical distance between vehicle center of gravity and tipping axis, in each case considered for the normal position of the vehicle on level ground. The acceleration due to gravity is designated as g, $C_1$ and $C_2$ are weighting factors; the acceleration due to gravity and the weighting factors are supplied to the functional element **4** together

with the vehicle geometry parameters as input signals "const." For calculating the reference retardation $a_{Ref}$.

The value of the first weighting factor $C_1$ depends on the determination of the actual vehicle retardation. For the case that the actual vehicle retardation is measured by means of the longitudinal acceleration sensor **2**, the value of the weighting factor $C_1$ is equal to zero and the reference retardation $a_{Ref}$ calculated only in relation to the cosine function. If the actual vehicle retardation is formed in the differentiator **3** by differentiation of the vehicle reference speed $v_x$, the value of the weighting factor $C_1$ amounts to one.

The degree of damping, respectively the prevention of overturning, is adjusted via the second weighting factor $C_2$. The maximum value of the second weighting factor $C_2$ amounts to one; in the case of this value the reference retardation $a_{Ref}$ reaches the tipping limit and the braking forces are so great that overturning of the vehicle can just be prevented. A safety margin to the tipping limit, that in particular takes account of overlapped dynamic portions of the oscillation, may be maintained by reducing the weighting factor $C_2$.

If the weighting factor $C_2$ again is reduced to a value clearly smaller that one, the distance to the tipping limit also is increased. Since the actual maximum vehicle retardation is oriented to the value reduced by the weighting factor $C_2$, only slight braking forces have to be applied, that lead to a correspondingly lower unlo0ading of the following wheels and correspondingly to more driving stability.

The angle of gradient $\alpha$ may be measured via a gradient sensor and supplied to the functional element **4** regularly at discrete time intervals for updating the reference retardation $a_{Ref}$. In this embodiment, the calculation of the reference retardation $a_{Ref}$ takes place on the basis of instantaneous, updated angles of gradient $\alpha$, so that at any moment of calculation the current angle of gradient is available in functional element **4** and correspondingly the reference retardation assumes the greatest possible value in each case, therefore the tipping limit is extended as far as possible.

For the case that no gradient sensor is available, a constant value is predetermined as a road gradient $\alpha$, that must correspond to a maximum value for safety reasons. In the case of a maximum value of the road gradient $\alpha$, the reference retardation $a_{Ref}$ assumes a minimum value, so that it is assured that the braking retardation is oriented to a minimum reference retardation and a sufficient distance from the tipping limit always is maintained in the case of all actual appearing road gradients.

The maximum value of the road gradient $\alpha$ preferably is oriented to the maximum climbing ability of the vehicle. In the case of a maximum climbing ability of 50% the maximum vehicle gradient amounts to $\alpha_{max}$ according to the relation

$\alpha_{max}$ = arctan (0.5)

approximately 27°.

Patent Claims

1. A method for reducing spin motions around a transverse axis in the case of braking a motor vehicle, the vehicle retardation ($a_{z,S}$, $a_{z,R}$) that is compared with a reference retardation ($a_{Ref}$) being supplied to a regulating and control unit (1) as an input signal , and in the case of exceeding the reference retardation ($a_{Ref}$) an adjusting signal ($S_{St}$) being generated for reducing the braking force of a vehicle brake, wherein the road gradient ($\alpha$) in the longitudinal direction of the vehicle is taken into account in the determination of the reference retardation ($a_{Ref}$), that is calculated in relation to the vehicle geometry according to the trigonometric relation

$$a_{Ref} = (I_h/h_s \cdot \cos(\alpha) - C_1 \cdot \sin(\alpha) \cdot g \cdot C_2,$$

wherein

$C_1$, $C_2$ designates weighting factors

$l_h$ designates the horizontal distance between vehicle center of gravity and tipping axis in the normal position of the vehicle,

$l_h$ designates the vertical distance between vehicle center of gravity and tipping axis in the normal position of the vehicle,

g designates the acceleration due to gravity, and

$\alpha$ designates the road gradient in the longitudinal direction of the vehicle.

2. The method according to Claim 1, wherein the vehicle retardation ($a_{x,S}$) is measured by means of a longitudinal acceleration sensor (2) and used as the basis of an input signal.

3. The method according to Claim 2, wherein the first weighting factor ($C_1$) amounts to zero.

4. The method according to Claim 1, wherein the vehicle retardation ($a_{x,R}$) is determined y differentiation of a vehicle reference speed ($v_x$) and is used as the basis of a regulation input signal.

5. The method according to Claim 4, wherein the first weighting factor ($C_1$) amounts to one.

6. The method according to one of the Claims 1 to 5, wherein the road gradient ($\alpha$) is measured in the longitudinal direction of the vehicle and supplied as input signal to the regulating and control unit (1).

7. The method according to one of the Claims 1 to 5, wherein the road gradient ($\alpha$) in the longitudinal direction of the vehicle is a constant value, that is stored in the regulating and control unit (1).

8. The method according to Claim 1, wherein the road gradient ($\alpha$) in the longitudinal direction of the vehicle is determined from the maximum climbing ability of the vehicle.

9. The method according to Claim 8, wherein 50% is assumed as the maximum climbing ability and correspondingly 27° is assumed as the road gradient ($\alpha$) in the longitudinal direction.

10. The method according to one of the Claims 1 to 9, wherein the regulation takes place in the case of backwards-directed travel downhill.

11. The method according to one of the Claims 1 to 10, wherein the second weighting factor ($C_2$) for preventing overturning around a tipping axis inclined transverse to the longitudinal axis of the vehicle is chosen to be at most equal to one.

12. The method according to at least one of the Claims 1 to 11, wherein the second weighting factor ($C_2$) is assumed to be smaller than one in order to prevent pitching motions.

1 page of drawings appended

DRAWINGS PAGE 1